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**WATERSHED-BASED ANALYSIS OF POLLUTION AND SEDIMENTATION FOR
THE WIDER CARIBBEAN**

Presented by

World Resource Institute

Watershed-based Analysis of Pollution and Sedimentation For the Wider Caribbean

Lauretta Burke, Jon Maidens and Stephen Menard
World Resources Institute
+1 (202) 729 7774
lauretta@wri.org

This analysis was performed as part of the *Reefs at Risk in the Caribbean* project. The project is implemented by the World Resources Institute (WRI) in collaboration with over twenty partner organizations across the region. The project receives support from the United Nations Foundation (via the ICran partnership), the US Agency for International Development, the Munson Foundation, the Henry Foundation, Environmental Defense, and the UNEP Caribbean Environment Program.

The Concept

Agriculture and other land use activities far inland can impact coral reefs through the increased delivery of sediment and pollution. A watershed-based analysis of land-based sources of pollution (LBS) was implemented to develop a preliminary estimate of this threat.

Preliminary Modeling Approach Overview

The following datasets were developed for the analysis - a fuller description of the model rules follows:

- **Relative Erosion Potential (REP)** for all land areas. We have implemented a simplified version of the Revised Universal Soil Loss Equation (RUSLE) (USDA, 1989) in order to estimate relative erosion rates for each 1km resolution grid cell. This formula combines slope, land cover type, precipitation and soil type;
- **Watershed boundaries** were derived at WRI and then the following indicators were calculated for each watershed;
 - **Mean relative erosion potential;**
 - **Relative river flow** which is based on precipitation within the watershed during the peak rainfall month. This serves as an indicator of relative river discharge;
 - Mean relative erosion potential and relative river flow are combined to estimate **relative sediment delivery**. *It should be noted that relative erosion rates and relative sediment delivery are being used as a proxy for both sediment and pollution delivery.*

From each river mouth (the pour point), sediment plumes can be estimated, based on the relative sediment delivery. This has not yet been done in this analysis, and is analytically complex.

Model results should be calibrated at each stage of the analysis – relative erosion rates, river discharge and sediment delivery at the river mouth, and areas impacted by sediment.

Model Rules Implemented for Preliminary Analysis

Step 1) Relative Erosion Potential (REP)

The first step of the analysis involves estimating likely erosion rates for each 1km resolution grid cell using a modified, simplified form of the Revised Universal Soil Loss Equation (RUSLE) (USDA, 1989). Information on slope, land cover type, precipitation, and soil porosity were integrated to develop an indicator of relative erosion potential (REP) for all land areas within the wider Caribbean.

Data Sets Used

REP relies upon four input data sets:

- a) **Percent slope** - derived from USGS HYDRO1K digital elevation model, 2000. (1000m resolution);
- b) **Relative erosion rate** by land cover type. The Global Land Cover Characteristics Database (USGS / Loveland, 2000), using International Geosphere-Biosphere Program land cover categories, was reclassified to give relative erosion rates, ranging from 15 (for forest) to 220 for barren or sparse vegetation.

LAND COVER CATEGORY	RELATIVE EROSION RATE
Water Bodies	5
Forest (All types of closed forest)	15
Closed Shrub land	45
Open Shrub land	50
Woody Savanna	60
Permanent Wetlands	80
Savannas	100
Cropland/Natural	120
Grasslands	125
Croplands	200
Urban and Built-up	210
Barren or Sparsely Vegetation	220

These relative erosion rates are based on published work involving conversion factors (Nyborg, 1995; FAO, 1979; Berner and Berner, 1987). (1000m resolution);

- c) **Precipitation** for the peak rainfall month (mm), based on monthly precipitation surfaces (0.08 DD resolution). This variable was chosen instead of mean annual precipitation because it is more indicative of the extreme rainfall events and because it captures more of the rainfall variability in the area. (9342m resolution);
- d) **Soil porosity**. A polygon database on soil type (FAO, 1995) provided soil texture and porosity attributes. Soil porosity is the soil characteristic used in calculations because of its relationship with infiltration capacity of the soil. (5000 m resolution).

Equation:

REP (by 1 km grid cell) =

$$\text{pct_slope} * \text{Land_cov_eros_rate} * \text{Precip_mm} * \text{porosity} / 1,000$$

Within this analysis, slope is the most influential input variable, followed by land cover, precipitation, and soil porosity. The most influential areas in the landscape in terms of high relative erosion rates are steep slopes with land converted to agriculture.

Step 2) Watershed Boundaries

New watershed boundaries were developed for the region using a modified DEM (USGS HYDRO1K, 2000). At WRI the DEM was “filled” and rivers and lakes were “burned” as to improve the accuracy of the watersheds. Rivers are based on HYDRO1k rivers. This resulted in a data set of more than 2,700 watersheds with a minimum size of 35 km².

Step 3) Mean REP and Relative River Flow

Two indicators that contribute to sediment delivery at the river mouth were calculated for each watershed:

- a) Mean relative erosion potential for the watershed (an indicator of average erosion rates for the basin) and
- b) Total rainfall within the watershed during the peak rainfall month (a proxy for river flow/discharge) which is expressed as Relative River Flow.

Step 4) Relative Sediment Delivery

An indicator of relative sediment delivery by watershed combines both relative river flow and mean relative erosion potential within the watershed.

Step 5) Calibration

Model Results should be calibrated at this point. It would be ideal to calibrate both relative estimates of river discharge, and relative sediment delivery for each river for which estimates are available.¹

Step 6) Plume Analysis *[NB Not yet implemented for the Caribbean]*

The final step in evaluating areas at risk from watershed-based sedimentation involves dispersing sediment from the river mouth. We are currently working to identify an appropriate circulation model for the Caribbean for this analysis.

Issues to Consider for Improving the Model

The preliminary analysis described above is our best effort using regionally-consistent data sources currently available to us. Some current limitations:

- Using a 1 km resolution DEM and a 35 sq. km. minimum watershed size results in the omission of many smaller watersheds. Some of the smaller islands have no identified watershed using this approach. We hope to remedy this once a high resolution elevation data set (90m resolution) becomes available.
- By integrating information on slope, current land cover, precipitation and soil, we get a rough estimate of present erosion rates, rather than change in erosion from a more natural state.
- Our data set on precipitation is fairly coarse-scale at roughly 9 km resolution. We are working to identify a higher resolution data set for the region.
- The current focus of the model is on sediment delivery. ***Are there any region-wide data sets which would improve the analysis with regard to nutrient pollution, such as agricultural land use of fertilizer application?***
- We are currently lacking in data available for calibration of the model. ***Are there any data sets on river discharge or sediment delivery for a large number of rivers?***

Validation

River discharge and sediment delivery estimates (ideally by month) are required for validation of this model. Please direct us to any relevant data sources. For now, your expert review is our first step toward validation. We welcome your comments on the maps provided.

¹ In the Southeast Asia analysis, statistics for river discharge had a correlation of .72 when compared with a data set of measured discharge for 120 rivers in the Philippines (UP/MSI, unpublished data), while there was a correlation of .52 between modeled and documented sediment delivery estimates (UP/MSI, unpublished data.)

Map Descriptions:

1. Watershed Boundaries for the Wider Caribbean

Preliminary Watershed (river basin) boundaries were developed at WRI under the *Reefs at Risk in the Caribbean* project. These watersheds were derived from the USGS HYDRO1K digital elevation data set, which has a grid resolution of 1000 m. Some rivers were corrected by "burning in" known river locations. A minimum watershed size of 35 sq. was used, which eliminates some small and erroneous watersheds and improves the overall quality of the dataset. As such, many small coastal watersheds are not included, and many small islands have no watersheds identified. (It is our intention to improve the mapping of watersheds for small islands once a more detailed elevation data set becomes available.)

2. Land Cover and Watershed Boundaries

Changing land cover and land use influences the amount of sediment, nutrients and other pollutants coming from the land. Typically, conversion from forest cover or other natural vegetation to agriculture results in increased erosion and increased nutrients coming from the land. Each Land cover type has an associated relative erosion rate. These rates are low for areas in dense forest cover, moderate for more open savannas and grassland, and highest on croplands and barren lands.

Land cover comes from USGS's 1km resolution Global Land Cover Characterization Data Base (GLCCDB), which is based on AVHRR satellite imagery from 1993.

3. Relative Erosion Potential (by square kilometer)

Relative Erosion Potential (REP) is a regionally consistent indicator of possible erosion rates across the landscape for the wider Caribbean. REP is evaluated for each 1km resolution grid cell, using a simplified version of the Revised Universal Soil Loss Equation. REP is a function of slope, land cover type, precipitation and soil type within each 1km resolution grid cell. REP increases with slope, precipitation and soil porosity. In addition, REP is elevated in areas where land cover has been converted from natural to agricultural or urban use.

REP was developed at WRI using the following four data sets:

- 1) Slope was derived from USGS's HYDRO1K Elevation data set.
- 2) Land Cover is based on USGS \ EROS Data Center's Global Land Cover Characterization Data Base (GLCCDB).
- 3) Precipitation for the peak rainfall month (in mm) was derived from GLOBAL ARC.
- 4) Soil Porosity estimates come from FAO's global soil data base.

4. Mean Relative Erosion Potential by watershed

Relative Erosion Potential (REP) is a regionally consistent indicator of possible erosion rates across the landscape for the wider Caribbean. REP is evaluated for each 1km resolution grid cell, using a simplified version of the Revised Universal Soil Loss Equation. REP is a function of slope, land cover type, precipitation and soil type within each 1km resolution grid cell. REP was summarized by watershed, with the mean value for the watershed presented on this map.

5. Relative River Flow by watershed

Precipitation for the peak rainfall month was summarized by watershed. This is intended to provide a rough indicator of relative river flow by basin. Sub-basins have been summarized, so all areas contributing to a single river mouth are treated as a single basin. Larger watersheds and those in wetter areas will have higher "relative river flow."

6. Relative Sediment Delivery by watershed

This estimate combines two watershed-based indicators presented on other maps – Mean Relative Erosion Potential and Relative River Flow by watershed. Combined, this provides an indicator which attempts to capture the effects of watershed size, precipitation, and landscape factors (slope, land cover and soil) which effect erosion and, ultimately, sediment and nutrient delivery at the river mouth.